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(54) **Reflective-type liquid crystal display and methods of forming the same**

(57) A paper-white reflective display (47) that has improved photopic white reflectance, a high contrast, a lack of haze or opaqueness when viewed from various viewing angles and lower drive voltages is described. The paper-white reflective display (47) includes first and second substrates (48, 50), a plurality of groups of liquid crystal and polymer layers (52, 54, 56) located between the first and second substrates (48, 50), each group of liquid crystal and polymer layers being reflective of different wavelengths of light, and a voltage source (58) connected between the first and second substrates (48, 50) that selectively applies a voltage to all of the liquid crystal and polymer layers (52, 54, 56).

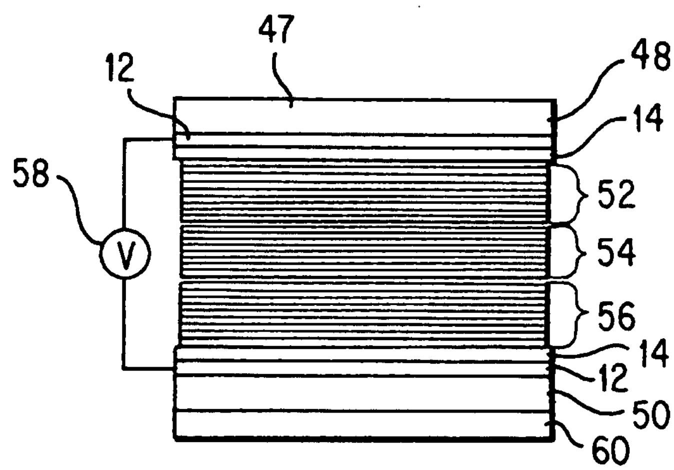

FIG. 6

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Description

The present invention relates to reflective displays and methods of forming the same. In particular, the invention relates to a paper-white liquid crystal reflective display and methods of forming the same.

Several types of reflective liquid crystal displays have recently been developed. Many of these reflective liquid crystal displays utilize liquid crystal-polymer dispersion technologies. Such displays are superior to conventional polarizer based displays for reflective mode operation.

An example of one type of such a reflective liquid crystal display is the polymer-dispersed liquid crystal (PDLC) display, which operates on the principle of electrically controlled light scattering. With this technology, liquid crystal droplets are embedded in a polymer matrix. In the off-state, the alignment of the liquid crystal droplets (symmetry axis) is random, resulting in an opaque, scattering film because of the mismatch between effective refractive index of the liquid crystal with that of the polymer. Upon application of an electric field, the liquid crystal within the liquid crystal droplets aligns parallel to the electric field and the composite material becomes transparent. However, contrast ratios in the direct-view reflective mode are in the 5-10:1 range and are strongly cell thickness dependent. Further, the reflectivity of the polymer dispersed liquid crystal reflective display is only about 12 to 15%.

Another type of reflective liquid crystal display is the polymer dispersed cholesteric liquid crystal display (PDCLC), which operates on the principle of Bragg reflection. Such cholesteric liquid crystal displays have a contrast ratio approaching approximately 10:1 with a photopic reflectivity of 10-13% under ambient lighting conditions and approximately 40% peak reflectivity at the Bragg wavelength.

Another type of reflective liquid crystal display is a polymer stabilized cholesteric texture (PSCT) reflective display. The polymer stabilized cholesteric texture reflective display uses a small amount of polymer additive in the cholesteric liquid crystal medium which assembles into an ordered stabilizing network. Contrast ratios have been reported between 20-30:1 with 10 to 15% photopic reflection under ambient lighting conditions, and nearly 40% peak reflectivity at the Bragg wavelength. Similar displays have been demonstrated without the polymer with comparable performance.

A more recent type of reflective liquid crystal display is the holographic polymer dispersed liquid crystal display. Such a display is reported in "Holographically formed liquid crystal/polymer device for reflective color displays", by Tanaka et al., as reported in the Journal of the Society for Information Display, Volume 2, No. 1, 1994, pages 37-40. Further developments by Tanaka et al. reported on optimization of such a holographic liquid crystal display in "Optimization of Holographic PDLC for Reflective Color Display Applications" in the SID '95 Digest, pages 267-270. This holographically formed polymer dispersed liquid crystal is formed using optical interference techniques (reflection holography) to form planes of liquid crystal droplets at predesignated positions within the sample setting up a modulation in the liquid crystal droplet densities. The resulting optical interference reflects the Bragg wavelength in the off-state when the liquid crystal material directors encapsulated within the droplets are misaligned. Upon application of an applied voltage, the periodic refractive index modulation vanishes if the refractive index of the liquid crystal is approximately matched with the refractive index of the polymer, and all incident light is transmitted. The spectral reflectance of the display is determined during the fabrication process and can be chosen to reflect any visible wavelength. The above-described holographic liquid crystal/polymer reflective color display is formed with an isotropic polymer which results in liquid crystal droplets being formed during the phase separation. Because the polymer is isotropic, the molecules of the polymer are randomly aligned and the display device has visible opaqueness or haze when viewed from an angle due to the mismatch between the effective refractive index of the liquid crystal and that of the polymer becomes enhanced at wide angles. Additionally, this display device requires a relatively large drive voltage due to the liquid crystal spherical droplets. In particular, the voltage necessary to drive the display device is proportional to the surface-to-volume ratio of the liquid crystal droplets. Such spherical droplets have a surface-to-volume ratio of 3/R where R is the radius of the droplet.

U.S. patent application attorney docket No. JAO 34133, entitled "HOLOGRAPHICALLY FORMED REFLECTIVE DISPLAY, LIQUID CRYSTAL DISPLAY AND PROJECTION SYSTEMS AND METHODS OF FORMING THE SAME", discloses holographically formed reflective displays and projection systems. U.S. patent application attorney docket No. JAO 34134, entitled "BROADBAND REFLECTIVE DISPLAY AND METHODS OF FORMING THE SAME", discloses broadening the reflective wavelengths by including a plurality of groups of reflective layers each being reflective of different wavelengths of light.

Additionally, there has recently been a great amount of interest in paper-white reflective displays. However, conventional technologies for producing such paper-white displays have produced displays with a low photopic white reflectance of, for example, 10-15%. If aided by passive light shaping elements (brightness enhancement films), the reflectance can be increased to 20-40% at the expense of contrast and viewing angle.

Accordingly, there is a need to provide a paper-white reflective display that has an improved photopic white reflectance, can operate at reduced drive voltages, has a high contrast and has a haze free appearance when viewed from different viewing angles.

In accordance with one aspect of the present invention, there is provided a paper-white reflective display,

comprising: first and second substrates; a plurality of groups of liquid crystal and polymer layers located between the first and second substrates, each of the plurality of groups of liquid crystal and polymer layers being reflective of different wavelengths of light; and at least one voltage source connected between the first and second substrates that selectively applies a voltage to the liquid crystal and polymer layers.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1(a) is a schematic view illustrating a reflective display prior to application of interfering lasers during assembly of the display;
Figure 1(b) is a schematic view illustrating the reflective display;
Figures 2(a) to 2(c) illustrate the homogenous and homeotropic surface boundary conditions of the reflective display in the off-state;
Figures 3(a) to 3(c) illustrate the homogenous and homeotropic surface boundary conditions of the reflective display in the on-state;
Figure 4 illustrates a full-color reflective liquid crystal display;
Figure 5 illustrates a projection system which includes three reflective displays;
Figure 6 illustrates a paper-white reflective display;
Figures 7(a) and 7(b) are graphs illustrating reflectance versus wavelength and a diagram showing the chromaticity of the white-point respectively for the paper white reflective display of Figure 6;
Figure 8 illustrates a paper-white reflective display having a plurality of sub-layers; and
Figures 9(a) and 9(b) are graphs illustrating reflectance versus wavelength and a diagram showing the chromaticity of the white-point respectively for the paper white reflective display of Figure 8.

Identical components are indexed alike.

Figure 1(a) illustrates a reflective display. Between substrates 10 are formed indium tin oxide layers 12 and alignment layers 14. Alignment layers 14 may be a rubbed polymer layer, where homogeneous surface boundary conditions are desired, or a silane surfactant layer, for example, where homeotropic (perpendicular) surface boundary conditions are desired, as will be further explained below. Displaced between the alignment layers 14 is a liquid crystal polymer mixture 16 comprising a anisotropic polymer 18 dissolved in a liquid crystal solvent. The anisotropic polymer 18 may include a photo-active monomer and suitable photo-initiator. The liquid crystal polymer mixture 16 is homogenized via mechanical agitation and heat.

The display is then irradiated with interfering laser beams A and B, for example, that set up interference fringes therewithin. The resultant structure 8 is illustrated in Figure 1(b). Regions within the liquid crystal/polymer mixture 16 that experience the high intensity of the interference pattern of the lasers become polymer rich and form polymer sheets 20 and those regions where the intensity is low become void of polymer and form liquid crystal regions 22. As can be seen in Figure 1(b), the polymer sheets 20 and liquid crystal regions 22 form into a multilayer structure.

The holographically formed reflective display 8 is illustrated in Figure 2(a) in an off-state. The off-state occurs when no electric field is applied between the indium tin oxide layers 12. In the off-state, the display is transparent and all light is transmitted through the display because the molecules of the liquid crystal regions 22 are effectively index matched and aligned with the molecules forming the polymer sheets 20.

The index matching in the off-state for homogeneous and homeotropic surface boundary conditions is illustrated in Figures 2(b) and 2(c), which are enlarged views of the liquid crystal layer 22 and polymer sheets 20 within circle 15 of Figure 2(a). In particular, Figure 2 (b) illustrates the homogeneous surface boundary conditions that are formed when the alignment layer 14 is a rubbed polymer layer. Such a rubbed polymer layer is well known to those of ordinary skill in the art and is formed by conventional rubbing techniques. The rubbed polymer layer causes the molecules within the polymer sheets 20 and within the liquid crystal regions 22 to form along the planar alignment direction of the nematic liquid crystal medium in a direction generally parallel to a surface of the substrate 10. As may be seen with reference to Figure 2(b), because the polymer molecules forming the polymer sheets 20 are anisotropic polymer molecules, the molecules are elongated and align in a single direction. Likewise, the molecules forming liquid crystal regions 22 are anisotropic and hence align in the same direction as the molecules forming the polymer sheets. This index matched alignment vastly reduces haze in the holographically formed reflective display 8 when it is viewed from various viewing angles. Conventional holographically formed reflective displays, in contrast, use isotropic polymers which are randomly aligned and thus create haze and opaqueness when viewed from various viewing angles.

Homeotropic surface boundary conditions for the reflective display 8 are illustrated in Figure 2(c), which is an enlarged view of the circle 15 shown in Figure 2 (a). The homeotropic surface boundary conditions are created when the alignment layer 14 includes perpendicular alignment. One example is a silane surfactant layer. This causes the anisotropic polymer within the polymer sheets 20 to align substantially perpendicular to a surface of the substrates 10 as illustrated in Figure 2(c). Likewise, because the molecules within the liquid crystal region 22 are anisotropic, they align in the same direction as the anisotropic polymer molecules forming the polymer sheets 20. Again, use of the anisotropic polymer greatly reduces haze and opaqueness in the holographically formed reflective display 8 when viewed

from various viewing angles.

Figure 3(a) illustrates the holographically formed reflective display 8 in an on-state. In the on-state, a voltage from a voltage source 24 is applied between the indium tin oxide layers 12. This creates an electric field in the direction illustrated by arrow E and causes the display to be reflective of light of a desired wavelength. The desired wavelength of the reflected light may be selected during formation of the device by appropriately controlling the wavelengths of the interference fringes created by the laser or other holograhic means used during device formation.

Figure 3(b) is an enlarged view of the area shown within circle 17 in Figure 3(a) for homogenous surface boundary conditions. Application of the electric field E between the indium tin oxide layers causes molecules with positive dielective anisotropy within the liquid crystal regions 22 to align parallel to the E direction, as illustrated in Figure 3(b). This causes light of a desired wavelength to be reflected while all other light is transmitted.

Homeotropic surface boundary conditions for the holographically formed reflective display 8 in the onstate are illustrated in Figure 3(c). For the case of homeotropic alignment, the liquid crystal material used is one with negative dielectric anisotropy. Here, application of the electric field E causes the molecules with negative dielectric anisotropy within the liquid crystal region 22 to align perpendicular to the E field direction causing light of the desired wavelength to be reflected.

A full-color liquid crystal display is illustrated in Figure 4. For the case of homogeneous surface alignment, the liquid crystal material used is one with positive dielectic anisotropy. The full-color liquid crystal display 26 includes three holographically formed reflective displays 25, 27 and 29 (which are similar to the holographically formed reflective display 8) each being reflective of a different wavelength of light. The full-color liquid crystal display 26 includes black absorber 28 which is used to absorb non-reflective wavelengths and enhance display contrasts. As illustrated in Figure 4, ambient light is exposed to the upper surface 31 of the full-color liquid crystal display 26 in the direction of arrow F. To form an image, the voltage sources 24 are each independently controlled to selectively reflect light (as indicated by arrow F') from each of the holographically formed reflective displays 25, 27, 29, each reflecting light of a different wavelength. For example, the upper reflective display 25 in Figure 4 may reflect light of 465nm, the middle holographically formed reflective display 27 may reflect light of 545nm and the lower holographically formed reflective display 29 may reflect light of 620nm, to reflect light of blue, green and red wavelengths respectively. By selectively activating the three holographic reflective display layers, a full-color image may be formed from incident broad-band illumination.

Figure 5 illustrates a full-color projection system 39 which includes a first holographically formed reflective display 30, which may selectively reflect red light having an approximate wavelength of 620nm, a second holographically formed reflective display 32, which may reflect green light of approximately 545nm and a third holographically formed reflective display 34, which may reflect blue light of approximately 465nm.

Light is input from a light source 36 and upon contacting the first holographically formed reflective display 30, red light having a wavelength of approximately 620nm is reflected in the direction of arrow G onto mirror 38 and reflected towards an output in a direction of arrow H. Light which is not of the red wavelength of approximately 620nm is transmitted by the first holographically formed reflective display 30 in the direction of arrow I to the second holographically formed reflective display 32. The second holographically formed reflective display 32 reflects light with a green wavelength of approximately 545nm in the direction of arrow J onto a surface of first dichroic mirror 40. First dichroic wavelength mirror 40 transmits the red light reflected by mirror 38 and reflects the green light in a direction of arrow H. Light from the light source 36 which is not reflected by the second holographically formed reflective display 32 is transmitted to the third holographically formed reflective display 34, which reflects light of a blue wavelength of approximately 465nm in the direction of arrow K onto a surface of second dichroic mirror 42.

Light which is not reflected by third holographically formed reflective display 34 is transmitted to light stop 35. Second dichroic mirror 42 reflects the blue wavelength light in the direction of arrow H and transmits the red and green light from mirror 38 and first dichroic mirror 40 to the output. In this way, an image may be formed and projected by the full-color projection system 31.

The above-noted reflective wavelengths for the first, second and third holographically formed reflective displays 30, 32 and 34 of the projection system 31 may be varied to the desired value by adjusting the wavelength of light that is reflected by each display to a desired value, as discussed above regarding the embodiments illustrated in Figures 2(a) to 2(c) and 3(a) to 3(c).

The above-described holographically formed reflective displays may achieve bistable switching by using a chiral nematic or ferroelectric liquid crystal material instead of a typical nematic liquid crystal material which would normally be used. Bistability is more fully discussed in a related application entitled "BISTABLE REFLECTIVE DISPLAY USING CHIRAL LIQUID CRYSTAL AND RECONFIGURABLE INORGANIC AGGLOMERATES" (Attorney Docket No. JAO 34136).

Figure 6 illustrates a paper-white reflective display 47. The paper-white reflective display 47 is similar to the reflective display 26 of Figure 4 except that the paper-white reflective display 47 includes only two substrates 48 and 50 between which three groups of liquid crystal and polymer layers 52, 54 and 56 are formed.

Each of the groups of liquid crystal and polymer layers 52, 54 and 56 may include one liquid crystal layer and one polymer layer or a plurality of liquid crystal lay-

ers and a plurality of polymer layers, in the same manner as illustrated in Figure 1(b), for example. Each of the groups of liquid crystal and polymer layers 52, 54 and 56 are formed as discussed above to be reflective of different wavelengths of light. For example, the group of liquid crystal and polymer layers 52 may be reflective of red light having a center wavelength of approximately 630nm, the group of liquid crystal and polymer layers 54 may be reflective of green light having a center wavelength of approximately 540nm, and the group of liquid crystal and polymer layers 56 may be reflective of blue light having a center wavelength of approximately 480nm.

Because the voltage source 58 applies or does not apply a voltage to substrates 48 and 50 and hence to each of the groups of liquid crystal and polymer layers 52, 54 and 56, the paper-white reflective display 47 will cause all of the groups of liquid crystal and polymer layers 52, 54 and 56 to be reflective or transparent at any given time. When the groups of liquid crystal and polymer layers 52, 54 and 56 are all in the reflective state, the paper-white reflective display 47 takes on a paper white appearance due to the combination of red, green and blue light all being simultaneously reflected.

The paper-white reflective display 47 also includes a black absorber 60 formed adjacent to substrate 50. The black absorber 60 acts as a light stop which absorbs non-reflected wavelengths, thereby enhancing display contrast and giving the display a black appearance when the liquid crystal and polymer layers 52, 54 and 56 are in a transparent state.

Figure 7(a) is a composite reflectance versus wavelength graph illustrating the reflectance of the paper-white reflective display 47 with the groups of liquid crystal and polymer layers 52, 54 and 56 being reflective of the above-described center wavelengths of light, each group being reflective of light having an approximately 40nm bandwidth. Figure 7(b) is a chromaticity chart of the paper-white reflective display 47 and illustrates the chromaticity value for the display white-point for the paper-white reflective display 47 and its desired proximity to DSO and D65 standard illuminants. The photopic reflectance of the white state is approximately 44%, as noted in Figure 7(b).

Figure 8 illustrates paper-white reflective display 62. For each group of liquid crystal and polymer layers 64, 66 and 68, the paper-white reflective display 62 includes a plurality of liquid crystal and polymer sub-layers each being reflective of a different wavelength of light. The illustrated embodiment includes nine liquid crystal and polymer sub-layers 70, 72, 74, 76, 78, 80, 82, 84, 86, three for each group. However, different numbers of groups or sub-layers may be used. The groups and sub-layers are tuned to particular wavelengths as described above regarding the embodiments described in with reference to Figures 2(a) to 2(c) and 3(a) to 3(c).

The group of liquid crystal and polymer layers 64 includes three liquid crystal and polymer sub-layers 70, 72 and 74 each being reflective of red wavelengths of light, but having their central wavelengths shifted from one another to broaden the spectral reflectance. The three liquid crystal and polymer sub-layers 70, 72 and 74 may have central wavelengths of 600nm, 630nm and 660nm respectively.

The group of liquid crystal and polymer layers 66 includes three liquid crystal and polymer sub-layers 76, 78 and 80 each being reflective of green wavelengths of light, but having their central wavelengths shifted from one another to broaden the spectral reflectance. The three liquid crystal and polymer sub-layers 76, 78 and 80 may have central wavelengths of 510nm, 540nm and 570nm respectively.

The group of liquid crystal and polymer layers 68 includes three liquid crystal and polymer sub-layers 82, 84 and 86 each being reflective of blue wavelengths of light, but having their central wavelengths shifted from one another to broaden the spectral reflectance. The three liquid crystal and polymer sub-layers 82, 84 and 86 may have central wavelengths of 460nm, 480nm and 500nm respectively. Each of the liquid crystal and polymer sub-layers may have a 40nm bandwidth.

Figure 9(a) is a composite reflectance versus wavelength graph illustrating the reflectance of the paper-white reflective display 62. The relative reflectance values of the green, red and blue peaks have been adjusted to achieve the desired white-point chromaticity. Because this embodiment greatly increases the bandwidth of the reflectance peaks compared to the reflective display of Figure 6, the photopic white reflectance is increased to 73%. Figure 9(b) is a chromaticity chart of the paper-white reflective display 62 and as illustrated, produces a desired white-point chromaticity in close proximity to the DSO and D65 standard illuminants.

Claims

1. A paper-white reflective display (26; 47; 62), comprising:

   first and second substrates (10; 48, 50);
   a plurality of groups of liquid crystal and polymer layers (16, 18; 25, 27, 29; 52, 54, 56; 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86) located between the first and second substrates (10; 48, 50), each of the plurality of groups of liquid crystal and polymer layers (16, 18; 25, 27, 29; 52, 54, 56; 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86) being reflective of different wavelengths of light; and
   at least one voltage source (24; 58) connected between the first and second substrates (10, 12; 48, 50) that selectively applies a voltage to the liquid crystal and polymer layers (16, 18; 25, 27, 29; 52, 54, 56; 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86).

2. A reflective display according to claim 1, further comprising a black absorber layer (26; 60) disposed adjacent to one (10; 50) of the substrates (10; 48, 50).

3. A reflective display according to claim 1 or 2, wherein the plurality of groups liquid crystal and polymer layers comprise three groups (25, 27, 29; 52, 54, 56; 64, 66, 68) of liquid crystal and polymer layers, a first group (25; 52; 64) being reflective of red wavelengths of light, a second group (27; 54; 66) being reflective of green wavelengths of light and a third group (29; 56; 68) being reflective of blue wavelengths of light.

4. A reflective display according to claim 3, wherein the red, green and blue wavelengths of light comprise wavelengths centered at approximately 630nm, 540nm and 480nm respectively.

5. A reflective display according to claim 1, 2 or 3, wherein each group of liquid crystal and polymer layers (64, 66, 68) comprises a plurality of liquid crystal and polymer sub-layers (70, 72, 74; 76, 78, 80; 82, 84, 86), each being reflective of different wavelengths of light.

6. A reflective display according to claim 5, wherein the groups of liquid crystal and polymer layers comprise first, second and third groups (64, 66, 68) of liquid crystal and polymer layers, the first group (64) comprising first, second and third liquid crystal and polymer sub-layers (70, 72, 74), the second group (66) comprising fourth, fifth and sixth liquid crystal and polymer sub-layers (76, 78, 80), and the third group (68) comprising seventh, eighth and ninth liquid crystal and polymer sub-layers (82, 84, 86).

7. A reflective display according to claim 6, wherein the first, second and third liquid crystal and polymer sub-layers are reflective of light having center wavelengths of approximately 600nm, 630nm and 660nm respectively, the fourth, fifth and sixth liquid crystal and polymer sub-layers are reflective of light having center wavelengths of approximately 510nm, 540nm and 570nm respectively, and the seventh, eighth and ninth liquid crystal and polymer sub-layers are reflective of light having center wavelengths of approximately 460nm, 480nm and 500nm respectively.

8. A reflective display according to any one of the preceding claims, wherein the liquid crystal layers are formed from one of a nematic, a chiral nematic or a ferroelectric liquid crystal material.

9. A reflective display according to any one of the preceding claims, wherein the reflective display operates in a reverse mode in which when no voltage is applied by the voltage source, the reflective display has a black appearance, and when a voltage is applied by the voltage source, the reflective display enters a white state having a paper-white appearance.

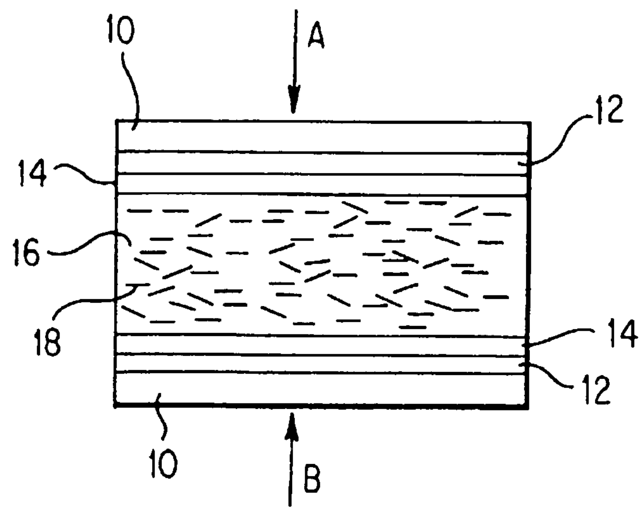


FIG. 1(a)

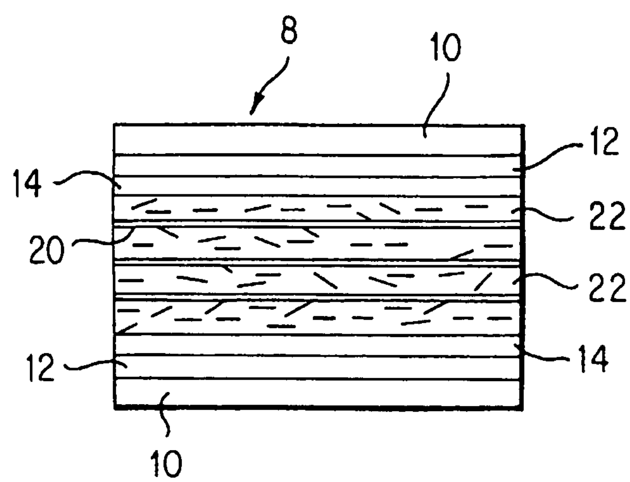


FIG. 1(b)

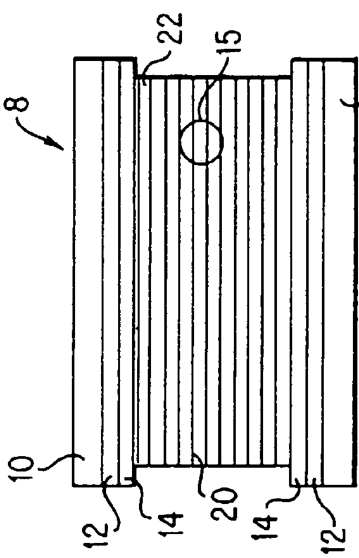


FIG. 2(a)

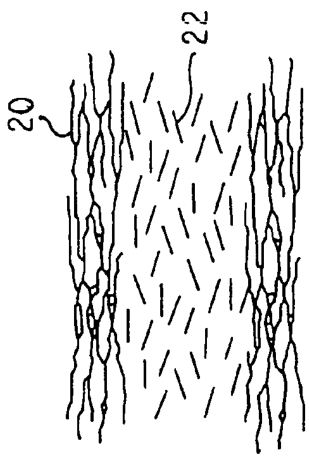


FIG. 2(b)

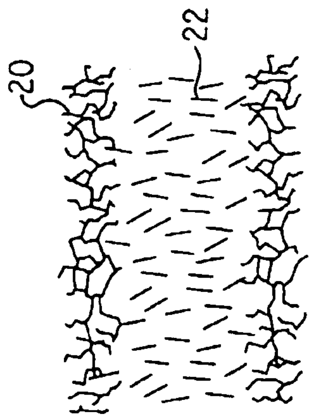


FIG. 2(c)

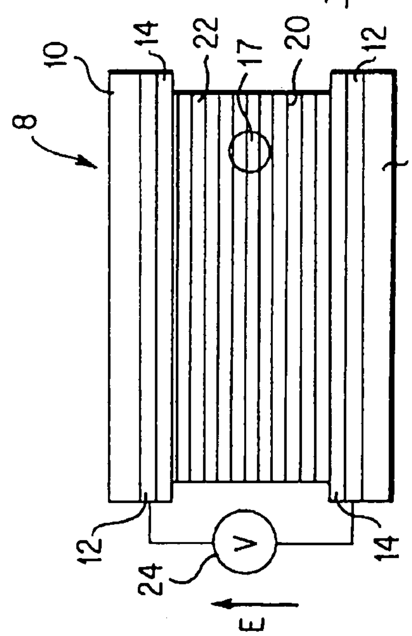


FIG. 3(a)

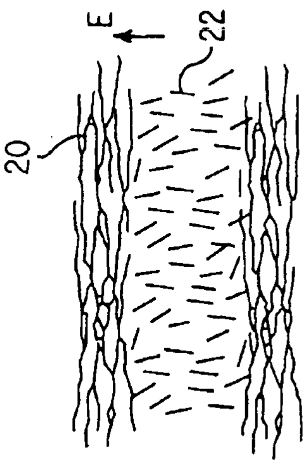


FIG. 3(b)

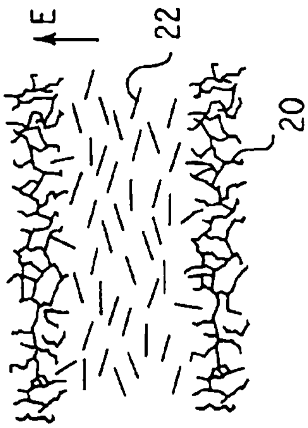


FIG. 3(c)

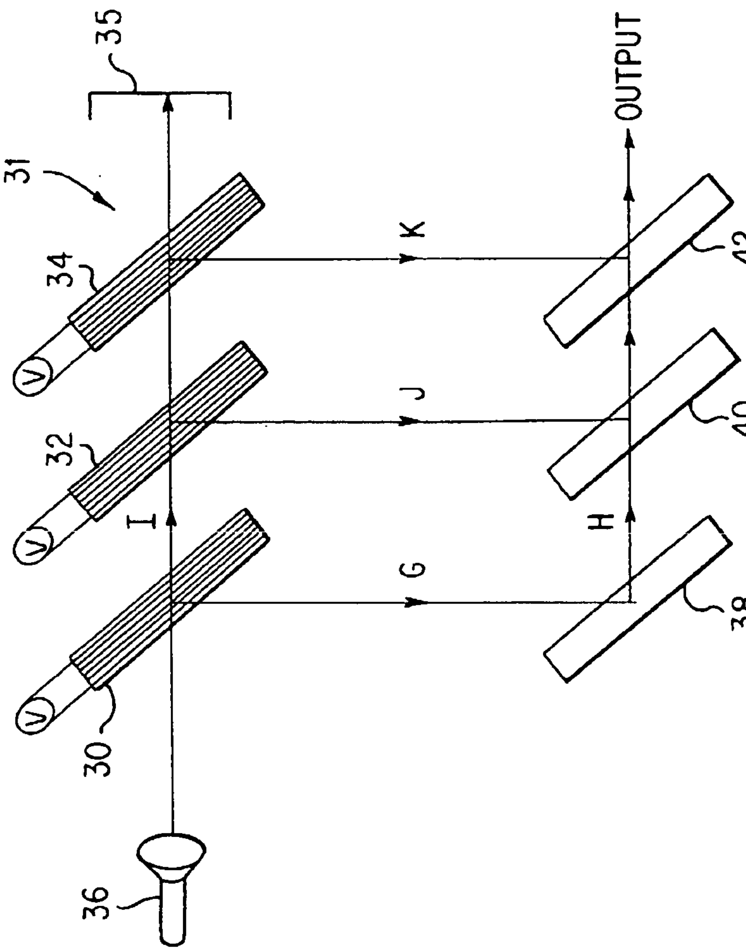

35
31
OUTPUT
34
32
30
36
K
J
I
G
H
42
40
38
V
V
V

FIG. 5

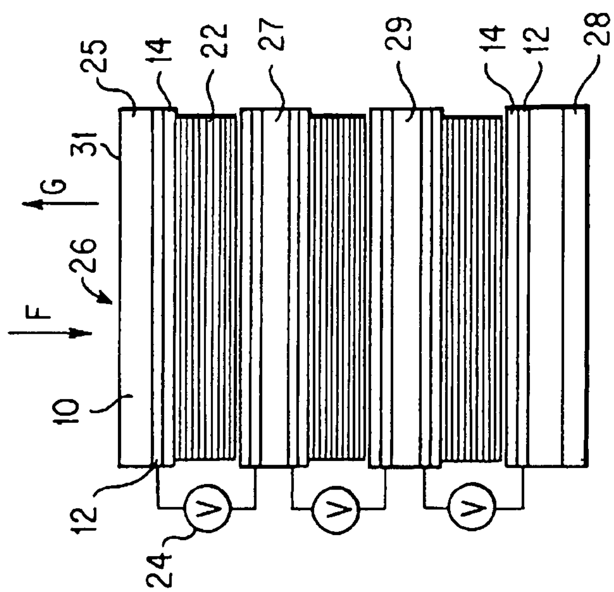

25
14
22
27
29
14
12
28
31
G
26
F
10
12
24
V
V
V

FIG. 4

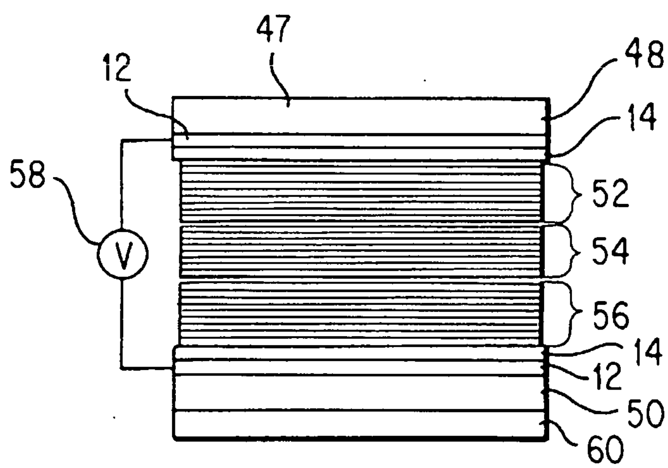


FIG. 6

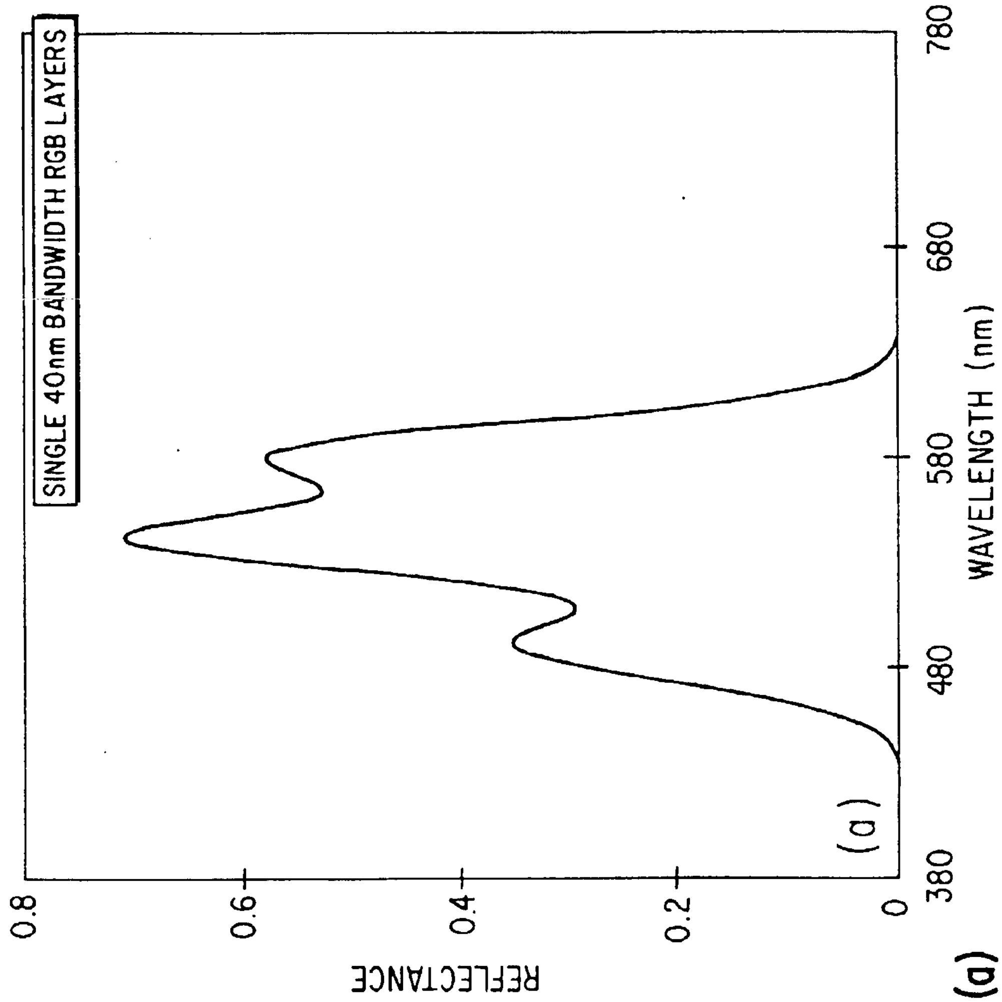
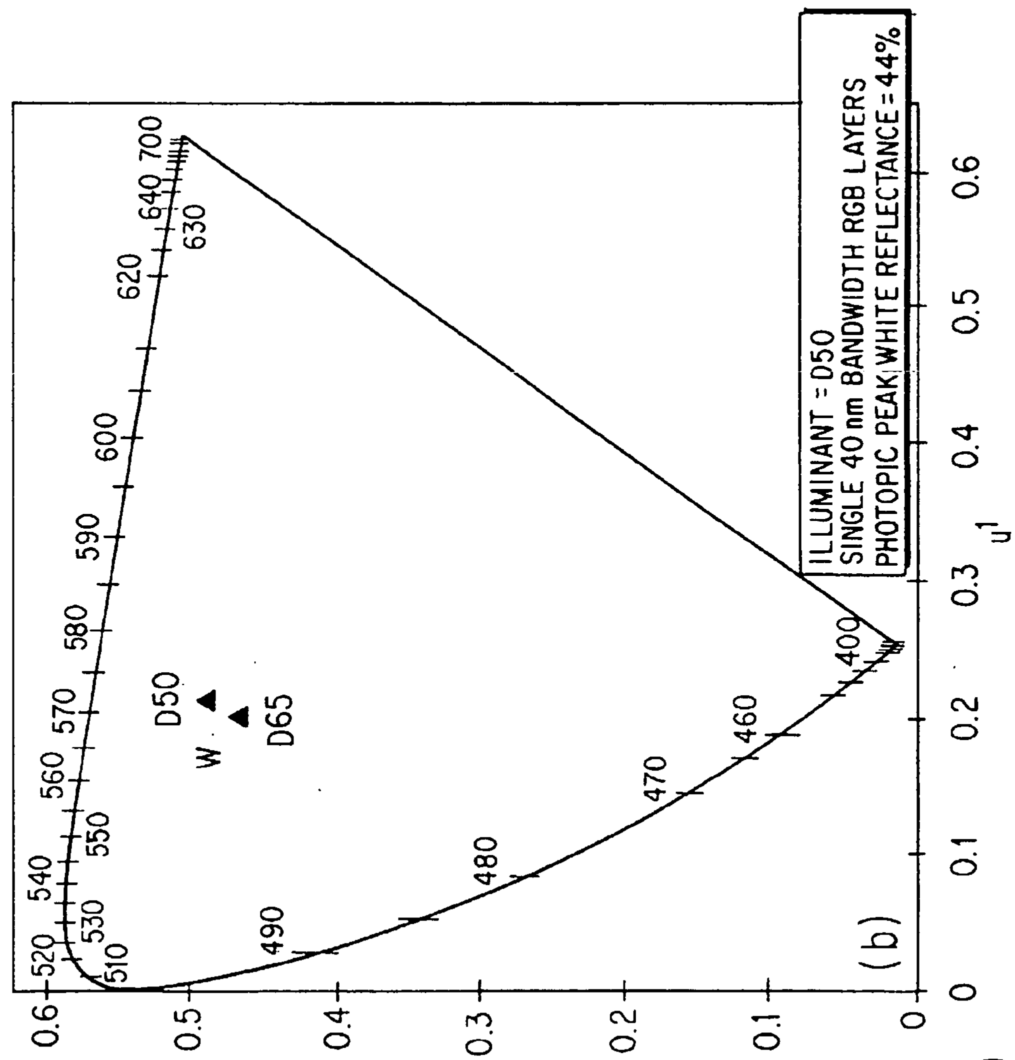

SINGLE 40nm BANDWIDTH RGB LAYERS
REFLECTANCE
0.8
0.6
0.4
0.2
0
380
480
580
680
780
WAVELENGTH (nm)
(a)

FIG. 7(a)


ILLUMINANT = D50
SINGLE 40 nm BANDWIDTH RGB LAYERS
PHOTOPIC PEAK WHITE REFLECTANCE = 44%
(b)
D50
D65
W
400
460
470
480
490
510
520
530
540
550
560
570
580
590
600
620
630
640
700
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v'
0
0.1
0.2
0.3
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0.5
0.6

FIG. 7(b)

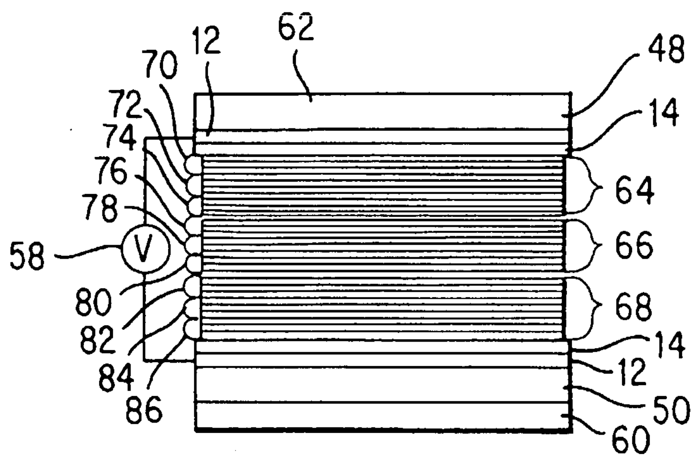

FIG. 8

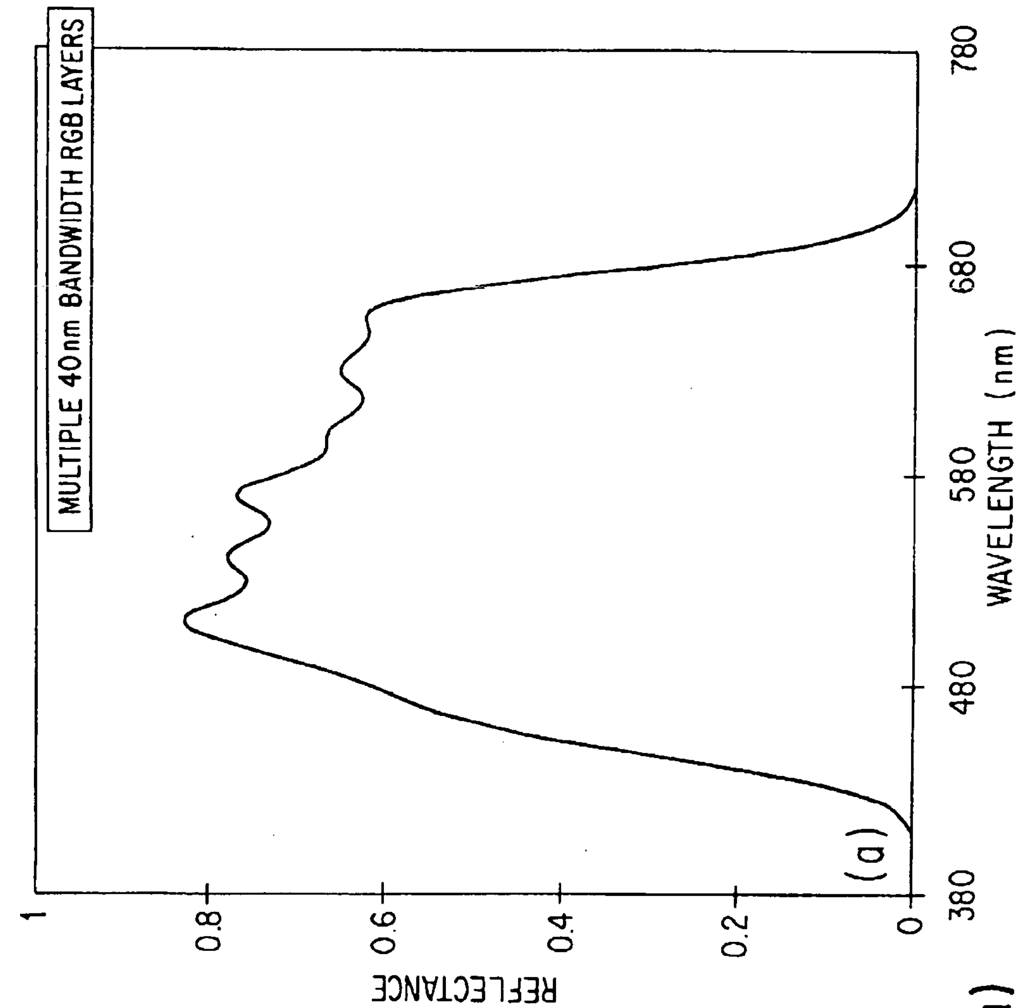
MULTIPLE 40nm BANDWIDTH RGB LAYERS
(a)
REFLECTANCE
0
0.2
0.4
0.6
0.8
1
380
480
580
680
780
WAVELENGTH (nm)

FIG. 9(a)

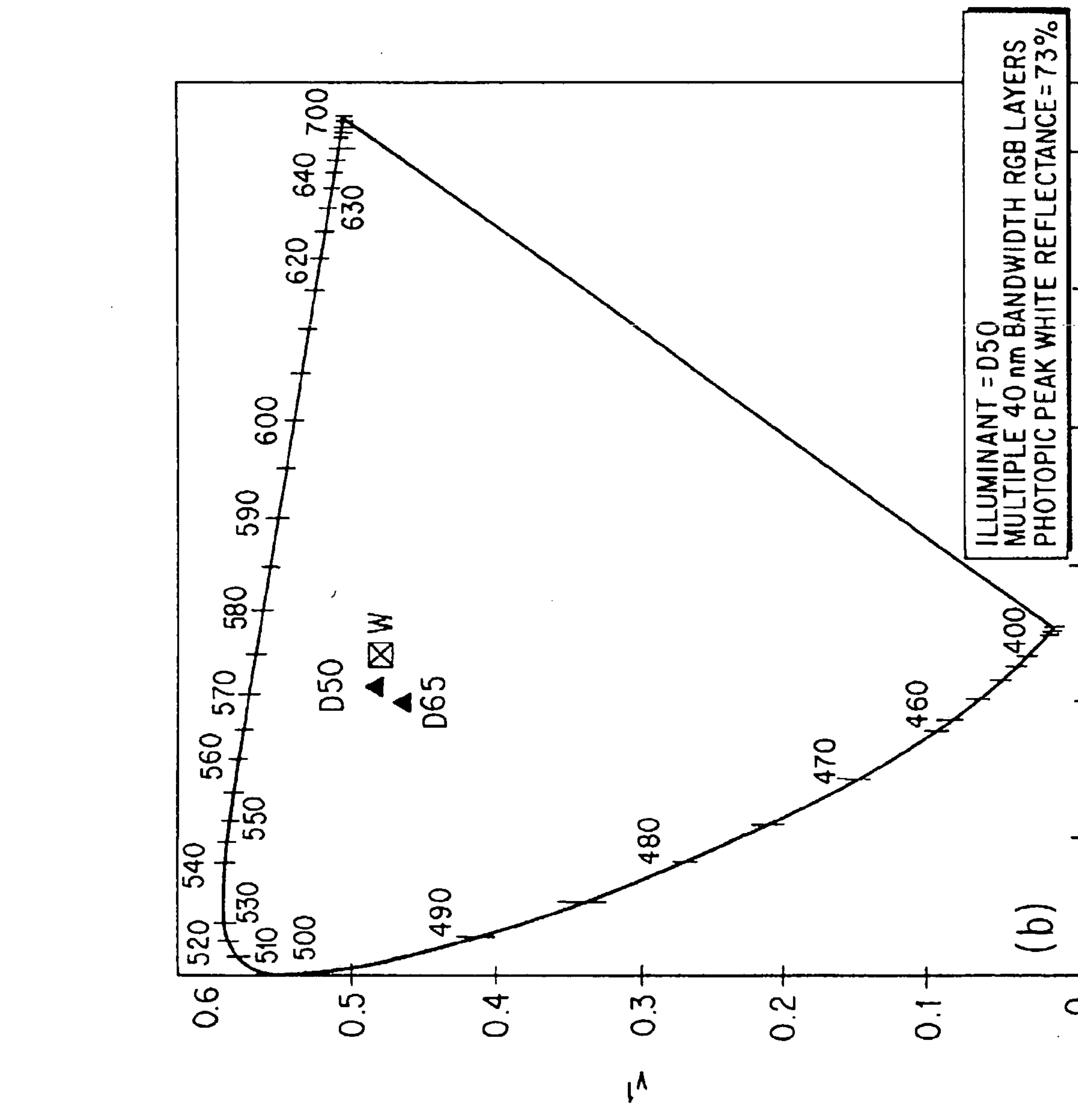
ILLUMINANT = D50
MULTIPLE 40 nm BANDWIDTH RGB LAYERS
PHOTOPIC PEAK WHITE REFLECTANCE = 73%
(b)
D50
D65
W
v'
u'
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
520
510
500
530
540
550
560
570
580
590
600
620
630
640
700
490
480
470
460
400

FIG. 9(b)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0468

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	TANAKA K ET AL: "HOLOGRAPHICALLY FORMED LIQUID-CRYSTAL/POLYMER DEVICE FOR REFLECTIVECOLOR DISPLAY" JOURNAL OF THE SOCIETY FOR INFORMATION DISPLAY, vol. 2, no. 1, 1 April 1994, pages 37-40, XP000482981 Sections "Introduction", "Structure and operation", and "Fabrication"	1,3,4,8, 9	G02F1/1333 G02F1/1347
Y	* figures 1-3 *	2	
Y	US 4 596 445 A (FERGASON JAMES L) * column 20, line 59 - line 68; figure 4 *	2	
D,A	TANAKA K ET AL: "OPTIMIZATION OF HOLOGRAPHIC PDLC FOR REFLECTIVE COLOR DISPLAY APPLICATIONS" 1995 SID INTERNATIONAL SYMPOSIUM DIGEST OF TECHNICAL PAPERS, ORLANDO, MAY 23 - 25, 1995, 23 May 1995, SOCIETY FOR INFORMATION DISPLAY, pages 267-270, XP000657150 Section "Principle of holographic PDLC" * figures 1,2 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G02F
A	US 5 200 845 A (CROOKER PETER P ET AL) * column 2, line 21 - line 36 * * column 5, line 19 - line 46; figures 1A,1B,4 *	1,3,4	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	27 April 1998	Petitpierre, O

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

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